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Habitat Selection by the Gopher Tortoise (*Gopherus polyphemus*)

Tracey D. Tuberville, Kurt A. Buhlmann, Harold E. Balbach,
Stephen H. Bennett, John P. Nestor, J.W. Gibbons, and
R.R. Sharitz

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Tracey D. Tuberville

*University of Georgia's Savannah River Ecology Laboratory
P.O. Drawer E
Aiken, SC 29802*

Harold E. Balbach

*Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
P.O. Box 9005
Champaign, IL 61826-9005*

Contributing authors:

*Kurt A. Buhlmann, University of Georgia, SREL and South Carolina DNR
Stephen H. Bennett, South Carolina DNR
John P. Nestor, University of Georgia, SREL
J.W. Gibbons, University of Georgia, SREL
R. R. Sharitz, University of Georgia, SREL*

Final report

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Abstract: The gopher tortoise (*Gopherus polyphemus*) occurs in the southeastern Coastal Plain and has experienced widespread decline due to habitat loss and other human impacts. The largest remaining populations occur on private lands and military installations. Proper management at these sites will be critical to the success of the species. The goal of this study was to determine the response of gopher tortoises to forestry management practices commonly implemented in the management of the red-cockaded woodpecker. We monitored habitat use of individual tortoises at four study sites with different ownership and management scenarios: Fort Gordon (military installation, winter burning), Savannah River Site (federal defense facility, winter burning, translocated population), Tillman Sand Ridge (state wildlife preserve, summer burning), and a private hunting preserve (no management). Habitat data were collected to characterize typical canopy and herbaceous vegetation of each site. Data were collected at active burrows; the anecdotal belief that tortoises select the most open habitat available was confirmed. The preferred habitat density appears to be in the range of 40 percent canopy cover, a value compatible with current woodpecker management guidelines. Results will be used to develop recommendations for the concurrent management of gopher tortoises and red-cockaded woodpeckers.

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Preface

The research documented in this report was performed during the period 2003 through 2004 as part of Work Unit CNN-T063, Effects on Forestry on Gopher Tortoise, part of the thrust “Training Lands Management-Characterization, Analysis, and Mitigation,” under program element A896, “Base Facilities Environmental Quality.” The Technical Monitor was Scott Belfit.

This research was conducted under the guidance of Dr. Harold Balbach, Principal Investigator, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL), in support of the Army Threatened and Endangered Species Research Program. Ms. Tracey Tuberville was the Savannah River Ecology Laboratory Principal Investigator. Funding for the South Carolina Department of Natural Resources portion of the project was provided through the State Wildlife Grants Program. Additional funding was provided by the U.S. Forest Service-Savannah River, and report preparation was aided by the Environmental Remediation Sciences Division of the Office of Biological and Environmental Research, U.S. Department of Energy, through Financial Assistance Award No. DE-FC09-96-SR18546 to the University of Georgia Research Foundation.

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At the time this work was performed, Steve Hodapp was the TES Program Manager, Alan Anderson was Chief, CEERD-CN-N, and Dr. John T. Bandy was Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL was Dr. Ilker Adiguzel.

Colonel Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

Background

The gopher tortoise (*Gopherus polyphemus*) occurs in the southeastern Coastal Plain and is the only tortoise species found east of the Mississippi River. It is associated with deep sandy soils and a wide variety of xeric habitats. Its historical habitat was the longleaf pine (*Pinus palustris*) forest, of which only about 2 percent remains (Noss et al. 1995). Due primarily to habitat loss, the species is considered declining throughout its range (Auffenberg and Franz 1982, Smith et al. in press). Although gopher tortoises are currently listed only in the western portion of their range (i.e., western Alabama, Mississippi, Louisiana; U. S. Fish and Wildlife Service [USFWS] 1987), many biologists familiar with the species believe that federal protection for the tortoise throughout its range is warranted. The USFWS has already been petitioned to list the Florida populations (Gopher Tortoise Petition January 2006).

Most of the remaining viable populations occur on private lands or military installations (Hermann et al. 2002, Smith et al. in press). If the gopher tortoise were to be federally listed, conflicts between training missions and stewardship missions could develop. Gopher tortoises frequently occur sympatrically with the federally listed red-cockaded woodpecker (RCW; *Picoides borealis*), but it is not known what effects federally mandated management for RCWs might have on gopher tortoises. To the extent that the military—and other major landowners with large tortoise populations—can implement habitat management strategies that are compatible for both species, thereby preventing the need to list the gopher tortoise, both military training missions and species conservation goals can be achieved simultaneously.

This project was initiated to determine the effects of habitat management for RCWs on space use by gopher tortoises by monitoring movements of individual tortoises at sites with a wide range of habitat management prescriptions. Specifically, we examined habitat selection, home range size, burrow use, and site fidelity of gopher tortoises under specific management scenarios to evaluate whether habitat management guidelines for RCWs recommended in the RCW recovery plan (USFWS 2003), as cur-

rently implemented on military installations, are complementary with management of gopher tortoises.

Objective

The study reported here had several objectives, but we will be concerned with only two of them. Although many biologists have observed that gopher tortoises prefer to make their burrows in the more open portions of their habitat, the characteristics of this “openness” have never been well quantified in terms of canopy cover and other vegetation characteristics. The first objective was to determine these factors for self-selected burrow sites within four habitats that illustrated a broad range of site characteristics.

Management prescriptions for the red-cockaded woodpecker have recently been reevaluated (USFWS 2003) and the degree of canopy cover and stem density now recommended for RCW management has been much decreased compared to previous recommendations. This raises the question among land managers who manage primarily for the RCW, and only secondarily for the tortoise, of whether the RCW management guidelines are suboptimal, acceptable, or excellent for the tortoises that may be living among the pine trees. The results of the forest cover measurements will be interpreted in terms of their relationships to RCW management prescriptions.

Scope

The four study sites were located at the northeastern limit of the species’ range in the Upper and Lower Coastal Plains of South Carolina and Georgia, an area in which the ecology of the species is relatively unknown. Collectively, these four sites provide a broad range of forestry management prescriptions. The level of detail presented in this report on the previous management and land use histories varies across study sites and reflects the information currently available for these sites.

Approach

The immediate focus of the studies reported here was on the tortoise populations at four locations in northeastern Georgia and adjacent southeastern South Carolina. The study sites were Fort Gordon, GA, the Department of Energy Savannah River Site, The South Carolina Department

of Natural Resources Tillman Sand Ridge state wildlife preserve, and a private hunting preserve in County SC. Fifty-nine different tortoises were identified, tagged, and tracked during two seasons to determine their habitat usage patterns. Vegetation data were collected at both randomly selected plots and in the immediate vicinity of selected tortoise burrows at all four study sites. The results of the vegetation sampling, especially the forest canopy cover data, were compared to relevant recommended red-cockaded woodpecker management guidelines to evaluate similarities and differences.

Mode of Technology Transfer

The information included in this report is one portion of the materials prepared by the Engineer Research and Development Center (ERDC) to assist installation natural resources and TES program managers. The gopher tortoise is the first species in a planned series of studies that treat management of Species at Risk as they relate to military installation management plans. The primary means of communicating the tortoise behavior information will be through publication in the scientific literature, as well as through the availability of this report. The specific data presented are intended to be used in the preparation of biological opinions related to planned Army actions where the gopher tortoise is present. The data also will be used for preparation of management plans, integrated natural resources management plans (INRMPs), and in the preparation of ecological risk assessments involving training and other land-disturbing activities where the tortoise is present. This report will be made accessible through the World Wide Web (WWW) at URL <http://www.cecer.army.mil>.

2 Background and Site Selection

Status of the Red-cockaded Woodpecker and Its Recovery

Status

The red-cockaded woodpecker is a federally listed endangered species endemic to open, mature, and old growth pine ecosystems in the southeastern United States. According to the “Executive Summary of the 2003 RCW Recovery Plan,” currently there are an estimated 14,068 red-cockaded woodpeckers living in 5,627 known active clusters across 11 states. This is less than 3 percent of estimated abundance at the time of European settlement. Red-cockaded woodpeckers were given federal protection with the passage of the Endangered Species Act in 1973. Despite this protection, all monitored populations (with one exception) declined in size throughout the 1970’s and into the 1980’s. In the 1990’s, in response to intensive management based on a new understanding of population dynamics and new management tools, most populations were stabilized and many showed increases. Other populations remain in decline, and most have small population sizes. The major challenge now is to bring about the widespread increases in population sizes necessary for recovery (USFWS 2003).

Habitat Requirements

Red-cockaded woodpeckers require open pine woodlands and savannahs with large old pines for nesting and roosting habitat (clusters). Cavity trees must be in open stands with little or no hardwood midstory and few or no overstory hardwoods. Hardwood encroachment resulting from fire suppression is a well-known cause of cluster abandonment. Red-cockaded woodpeckers also require abundant foraging habitat. Suitable foraging habitat consists of mature pines with an open canopy, low densities of small pines, little or no hardwood or pine midstory, few or no overstory hardwoods, and abundant native bunchgrass and forb groundcovers (USFWS 2003).

Open stands of pines with a minimum age of 80 to 120 years, depending on the site, provide suitable nesting habitat. Longleaf pines (*Pinus palustris*) are most commonly used, but numerous other species of southern pine are also acceptable. Nest cavities, and successful colonies, have been

found in loblolly (*P. taeda*), shortleaf (*P. echinata*), slash (*P. elliottii*), and Virginia (*P. virginiana*) pines, and occasionally other species, with and without association with longleaf. Foraging habitat is provided in pine and pine hardwood stands 30 years old or older with foraging preference for pine trees 10 inches (25.4 cm) or larger in diameter. In good, well-stocked, pine habitat, sufficient foraging substrate can be provided on 80 to 125 acres (32.4 to 50.6 hectares). The main criterion appears to be that the cavity trees must be of adequate size (at least 30 cm in diameter, and preferably larger), and spaced such that the canopy is not continuous. Mixed pine species are tolerated well if these criteria are met, and a mixture of scattered hardwoods often is seen to be accepted so long as they are not allowed to form a continuous, shaded canopy, either upper or mid-story. Dense stands (stands that are primarily hardwoods, or that have a dense hardwood understory) are avoided (USFWS 2003).

RCW Recovery Plan Guidelines for Habitat Management

The habitat described above is not typical of that found at the present time across most of the former RCW range, significant portions of which are, or were, shared with the gopher tortoise. The 2003 recovery plan for the RCW (USFWS 2003) gives the above description of high-quality RCW foraging habitat, as well as specific management targets for maintaining or restoring high quality foraging habitat. In general, the "... key components include: (1) native, site-appropriate canopy pine species, (2) old-growth pines, (3) lower density of canopy pines than in most second and third-growth forests, and (4) healthy forb and bunchgrass groundcovers." The overall structure of the habitat should consist of large, widely spaced pines (preferably native longleaf) with few smaller-sized pine trees, few canopy hardwoods, an absent or very low mid-story shrub component, and abundant native ground cover vegetation. Group size, reproductive success, and stand selection are positively correlated with these variables (USFWS 2003, and references cited therein).

Specific targets for managing for high quality RCW foraging habitat include:

- large pines (≥ 35 cm dbh and ≥ 60 yrs age): 45+ stems/ha,
- mid-sized pines (25.4-35 cm dbh): basal area (BA) ≤ 9.2 m²/ha,
- small pines (< 25.4 cm dbh): < 50 stems/ha and BA is < 2.3 m²/ha,
- mid-sized + large pines (all pines ≥ 25.4 cm dbh): BA ≥ 9.2 m²/ha,

- canopy hardwoods: absent or <10% of canopy in longleaf pine forest, <30% of canopy in loblolly pine forests,
- hardwood midstory: absent or <2.1m in height,
- herbaceous groundcover: $\geq 40\%$ cover.

One of the most important and effective management tools for restoring and maintaining the desired habitat structure is prescribed fire. The RCW recovery plan recommends early to mid-growing season fire every 1 to 5 years to maintain habitat (USFWS 2003). Sites needing intensive management (e.g., hardwood control) and restoration, should initially be burned every 1 to 3 years, with non-growing-season fires implemented as needed to reduce fuel loads. However, once the desired fuel-reduction has been achieved, prescribed fires should be switched to growing season fire.

Although a “... common anxiety is that prescribed burning during growing season may have detrimental effects on non-target species,” the low incidence of documented direct mortality to other species (such as game species and neotropical migratory birds) is a minor concern relative to the benefits that they obtain from maintenance of the forest structure (USFWS 2003). Early growing-season fires, compared to late growing-season or non-growing-season fires, also more closely mimic historical natural processes, are less likely to cause mortality of overstory pines, promote native ground cover, and more effectively control midstory shrubs. However, at sites needing intensive management or where fire is difficult to implement, mechanical removal or chemical control methods may need to be used—either alone or in combination with fire.

Habitat Management Guidelines for Gopher Tortoises

The recovery plan for the western population (Louisiana, Mississippi, and western Alabama) of gopher tortoises provides minimal guidance on how to manage their habitat. Beyond stating that an “abundance of herbaceous ground cover” and “a generally open canopy and sparse shrub cover” characterize good tortoise habitat (USFWS 1990), no specific management targets are provided. Although the need for more detailed habitat requirements of tortoises and specific management targets was noted more than a decade ago (Burke and Cox 1988, Germano and Bury 1994), few data are currently available.

The following management targets have been suggested for gopher tortoises based on studies conducted since the publication of the 1990 recovery plan:

- canopy cover: \leq 60% (Wilson et al. 1997); Berish (2001) recommends a mosaic of small treeless patches intermixed with forested areas with \leq 50-70% cover and canopy cover of \leq 30-40% for most of the site,
- pine BA: 30 m²/ha (Aresco and Guyer 1999),
- prescribed fire: growing season burn every 2-5 yrs, with an initial non-growing season fuel-reduction fire and more frequent growing season burns (every 1-3 yrs) for sites in need of intensive management. Where growing-season fire is not possible, more frequent non-growing season fires (every 1-2 yrs) should be implemented (Aresco and Guyer 1999, Berish 2001, Cox et al. 1987, Wilson et al. 1997).

Other variables, based on one or more studies of movement patterns and burrow use, that appeared to influence space use by gopher tortoises in at least some cases, include:

- total BA, hardwood BA, tree density (Aresco and Guyer 1999),
- total herbaceous cover (Auffenberg and Iverson 1979, Cox et al. 1987),
- percent cover of wiregrass, other grasses, and legumes (Cox et al. 1987, Garner and Landers 1981)
- shrub cover (Cox et al. 1987).

Study Sites

The four study sites for this research were located at the northeastern limit of the species' range in the Upper and Lower Coastal Plains of South Carolina and Georgia (Figure 1), an area in which the ecology of the species is relatively unknown. Collectively, these four sites provide a broad range of forestry management prescriptions (Table 1). The level of detail presented in this report on the previous management and land use histories varies across study sites and reflects the information currently available for these sites.

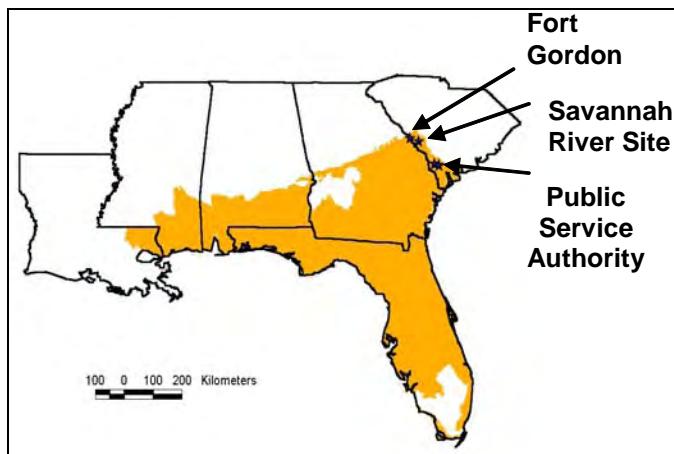


Figure 1. Location of four study sites in relation to distribution of the species (shaded).

Table 1. Designation of study sites and their background status.

Study Site	Land ownership	Land use	Management prescription
Fort Gordon (FTG)	U.S. DOD	Military training	Burn ¹ + mechanical removal of hardwoods
Tillman Sand Ridge Heritage Preserve (TSR)	SCDNR	Wildlife preserve	Growing season burn
Public Service Authority (PSA)	Private	Hunting preserve	No management
Savannah River Site (SRS) – translocated population	U.S. DOE	Defense facility	Dormant season burn

¹Both growing season and dormant season burns are conducted

Tillman Sand Ridge Heritage Preserve (growing-season burn)

Tillman Sand Ridge Heritage Preserve (TSR; Figure 2) is located in Jasper County, in the extreme southeastern corner of South Carolina. The preserve is owned and managed by South Carolina Department of Natural Resources specifically for the purpose of managing the resident gopher tortoise population. Previous surveys for gopher tortoises were conducted in 1974-1975 (Auffenberg and Franz 1982), 1977-1979 (Wright 1982), and 1998 (Tuberville and Dorcas 2001) and indicate that the TSR population of gopher tortoise is the largest in the state. Although RCWs do not actually occur on the preserve, breeding populations are known from Webb Wildlife Center (also owned by SCDNR), which is within 10 km of TSR.

The preserve is approximately 360 ha in size, and includes lands along the Savannah River. Vegetation alliances are approximately 55 percent xeric

sandhill, 28 percent bald cypress (*Taxodium distichium*)-tupelo gum (*Nyssa* spp.) swamp, and 17 percent mixed hardwoods (Dozier and Stowe 1999). The lower-lying lands, about half the area, are not tortoise habitat. The property had been owned by a commercial timber company and the planted slash pine (*Pinus elliottii*) stands were heavily thinned prior to its acquisition by SCDNR in 1984. Longleaf pine (*P. palustris*) has since regenerated on the site, both naturally and through planting of seedlings. The site has been burned approximately every 3 to 5 years for the past 12 years, primarily during the growing season (May – July). The groundcover is dominated by wiregrass (*Aristida stricta*) but also includes a diversity of other herbaceous species (Tuberville 1998). All soils are of the Buncombe Association (USDA 1980; per Coker and Murphy 1993).



Figure 2. Tillman Sand Ridge (TSR) Heritage Preserve.

Public Service Authority (no overall management)

The Public Service Authority property (PSA; Figure 3) was acquired by the state of South Carolina in 1985 as a potential utilities production site but is currently under lease to a private hunting club. This site supports few pine trees of sufficient size and age to provide cavity sites for RCWs, which are absent from the site. All merchantable timber was removed in the late 1980's and the tract has not been burned in at least 20 years. The tract is approximately 400 ha, the majority of which is underlain by Buncombe fluvial sands, suitable for gopher tortoises. The PSA is approximately 3.5 km northwest of TSR (from center to center). The hunt club management includes several food plots planted for deer and narrow (<5m wide) grassy strips maintained for quail.

Although tortoises are numerous at this site, they are primarily restricted to maintained open areas, roadsides, and adjacent forest edges. The only known survey work was initiated by SCDNR at the beginning of this study.

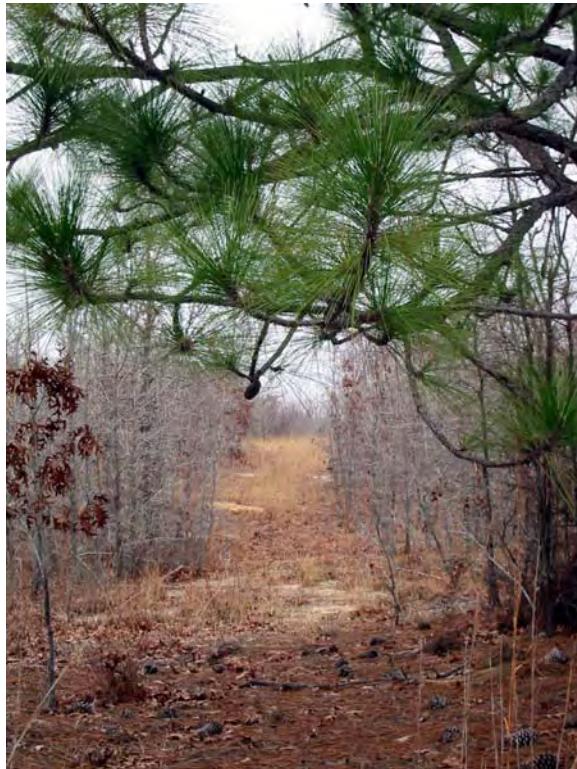


Figure 3. Public Service Authority (PSA) property illustrating the maintained grassy strips, dense hardwood understory, and lack of large pine trees.

Fort Gordon Military Reservation (growing season burn + mechanical removal)

Fort Gordon (Figure 4) is located in portions of Richmond, McDuffie, and Columbia Counties, Georgia, approximately 13 km southwest of Augusta. The reservation is 22,400 ha in size. Fort Gordon was established in 1941 as Camp Gordon, became Fort Gordon in 1956, and since 1974 has been the home of the Army Signal School.

The reservation is divided into three Habitat Management Units (HMUs) for the federally endangered RCW. HMU-1, approximately 8000 ha, is the area of main RCW concentration (the center 1/3 of Fort Gordon) and the management goal is to burn on a 3-year cycle. This study was restricted to Training Areas (TAs) 21 and 22 in HMU 1. The predominant soils in these areas are Lakeland and Troup, both sandy soils suitable for tortoises. Both growing-season and dormant-season fires are implemented, but Training Areas 21 and 22 are the only areas on the installation in which mechanical removal of mid-story vegetation (followed by growing-season fire) is routinely conducted, either with bulldozer or drum chopper. Forest stands within the training areas vary in age of stand and timing of management treatments. This study was conducted in both mature and young forests (Figure 4). The stands in which this study was conducted were most recently treated with growing-season fire in 2000 and/or 2001, non-growing-season fire in 2000 and/or 2002, and mechanical removal in 2000, 2002 or 2003.

Disturbance due to military training in our study areas is low intensity and very localized, both spatially and temporally. Military training throughout the reservation is primarily restricted to foot traffic; off-road, tracked vehicles are not routinely used. The only regular mechanized training (using tracked vehicles) occurs about 2 to 3 times per year as part of the National Guard training exercises. Within TA21 and TA22, the military actively avoids training in these training areas because of potential conflicts with RCWs.

Previous survey work for tortoises was conducted by USFWS in 1991 to identify concentrations of tortoise burrows, although the burrows were neither enumerated nor spatially located in that survey. Since 2002, The Nature Conservancy-Fort Gordon staff has resurveyed sites of burrow concentrations that have been treated with fire since the last growing season.



Figure 4. Fort Gordon young pine (top left) and mature pine (top right) forests.

Also shown is another nearby stand (bottom center) in which mechanical removal of the hardwoods had recently been conducted.

Savannah River Site

The Savannah River Site (SRS; Figure 5) is a 750 sq km Federal Reserve located in Aiken County, South Carolina. The SRS is owned by the U.S. Department of Energy and managed by the U.S. Forest Service. The portion of the SRS where this study was conducted is in the northeast corner in a 882-ha timber management compartment. Thirty-seven percent of the stand occurs on Lakeland and 25 percent on Troup series soils, both with high sand content and suitable for tortoises. The forest type is primarily open-canopy longleaf pine (52 percent of compartment area),

flanked by floodplain sweetgum (*Liquidambar styraciflua*) forests (13 percent), and interspersed with small patches of open-canopy loblolly pine (*P. taeda*), open-canopy mixed pines, upland hardwoods, and upland scrub forests (5 to 6 percent each). Longleaf pine has the highest dominance relative to other canopy species (86.4 percent) and the highest importance value (78.2), followed by loblolly pine (importance value 22.6 [K. Madden, unpublished data, SREL]). The estimated age of the timber stand is approximately 50 to 60 yrs (P. Johnston, professional communication, USFS-Savannah River). The understory comprises a mixed-oak (*Quercus* spp.) shrub layer and a moderately dense and diverse herbaceous layer.

Most management is directed toward improving site conditions for the federally-endangered RCW (USFWS 1970). A portion of the site had been replanted in wiregrass (*A. stricta*), which had been eliminated on most of the SRS due to intensive agriculture prior to SRS's acquisition by DOE in the 1950s (White and Gaines 2000). The forest stand is burned approximately every 3 years, usually in the dormant season. It was most recently burned in spring 2001 and February 2003.

The SRS tortoise population was translocated to the SRS in fall 2001, and the process and its characteristics have been described elsewhere (Clark 2003, Tuberville et al. in press).



Figure 5. Gopher tortoise study site on the Savannah River Site (SRS).

3 Methods

Tortoise and Burrow Location Identification

Tortoises were trapped using wire live traps placed at the entrance of tortoise burrows and covered with shade material. Traps were checked at least once every day. All tortoises were measured, sexed based on degree of plastral concavity (Iverson 1980; Landers et al. 1980), and permanently marked by drilling or filing notches in unique combinations of marginal scutes (Gibbons 1990). Only adult tortoises were used in this study. Each tortoise was fitted with a radio-transmitter (#LF-2-2/3A-CTM-RS-T, LL Electronics, Mahomet, IL; wt 40 g with epoxy) mounted on the carapace.

Animals were located 2 to 3 times per week during the 2003 and 2004 active seasons. Burrows were marked and assigned a unique number. All tortoise and new burrow locations were recorded using GPS technology (Trimble Pro-XR, Sunnyvale, CA, with sub-meter accuracy). The movement tracking was conducted for a concurrent related study, and will not be discussed in any detail in this report.

Vegetation Sampling

Vegetation data were collected at both randomly-selected plots (hereafter, called “random plots”) and in the immediate vicinity of selected tortoise burrows at all four study sites during September to October 2004. Trees were sampled using the point-quarter method. The following data were recorded for the nearest live tree >2.5 cm diameter at breast height (dbh) in each quadrant: distance (m), dbh in cm, and tree type (pine, oak, other hardwood). In addition, percent canopy cover was estimated in each quadrant using a spherical crown densiometer and averaged over the four quadrants. Percent shrub cover was estimated in 2m x 2m plots using the Braun-Blanquet cover score scale (absent, <5%, 5-25%, 25-50%, 50-75%, 75-100%). Wiregrass, other grass, legumes, and other forbs were similarly quantified in 1m x 1m herbaceous plots. Herbaceous plots were nested within shrub plots.

Potential locations of random plots were generated in ArcView 3.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA) using the RANDOM POINTS Extension. Random plots were a minimum of 50 m

from each other and at least 10 m from a road or tortoise burrow. The target sampling intensity was 1 random plot per 1 to 2 ha of study area (i.e., the forest stand or stands which tortoises were known to use, as evidenced by the radio-tracking data). Burrows were selected from the list of burrows known to be used on at least 3 occasions by the animals radio-tracked during this study, and thus were considered “regularly used.” Burrow plots were placed 1 m behind the burrow entrance to minimize potential impacts (e.g., soil disturbance, feeding) that tortoises might have on the vegetation surrounding their burrows (Boglioli et al. 2000). On the SRS, burrow plots included both tortoise-created burrows and starter burrows provided to tortoises at the time of their initial release at the translocation site. All SRS starter burrows that were sampled were verified to have been used by radio-tracked animals during the study period.

Statistical Analyses

Vegetation data were analyzed by comparing mean ranks among sites using Kruskal-Wallis and by comparing mean ranks between random plots and burrows using the Wilcoxon rank sum test. Prior to analyses, cover class scores were converted to percentages using the midpoint of the corresponding cover class. Alpha was set at 0.05 for all statistical procedures.

4 Results

Comparison of Available Habitat Among Sites

Tree Data

The following habitat measures were significantly different among random plots from the four study sites: percent canopy cover, total BA, pine BA, oak BA, percent of total BA comprised of pine, and proportion of total BA comprised of oak ($p < 0.0001$ for all comparisons). Percent canopy cover under growing season burn (hereafter, GS-burn; i.e., TSR) was significantly lower (38.4 percent) than all other management prescriptions, which had canopy cover values of approximately 55 percent (Figure 6). The GS-burn also had the lowest total BA and second lowest stem density. The canopy consisted of a few moderate-sized pine trees and many small oaks in the understory (as indicated by the low total BA but high relative percent BA represented by pine, and the moderate oak BA but high relative BA for oak; Table 2).

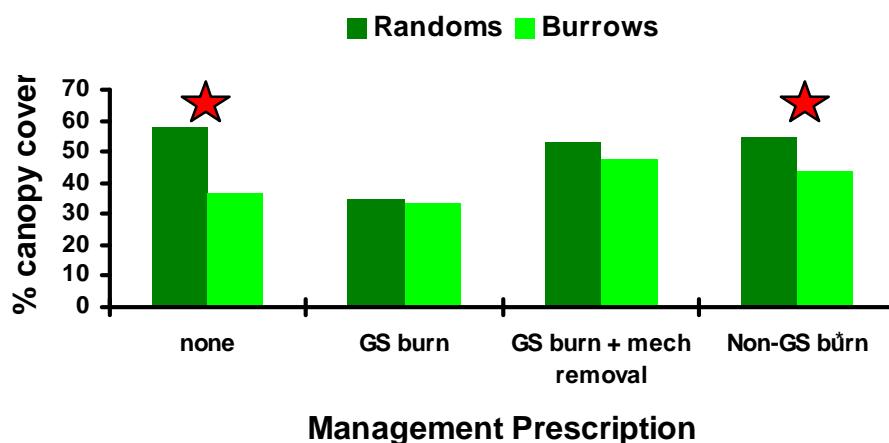


Figure 6. Percent canopy cover at random plots and burrows within each management prescription.

Significant comparisons between random plots and burrow locations are noted with a star.

Table 2. Summary of tree data at random locations in each management prescription.

These areas represent “available habitat.” Basal area (BA) is reported in m²/ha and density (D) as stems/ha. Importance values (I.V.) and relativized values of BA and D are also reported. In addition to overall means, separate means for young and mature pine stands are provided for the GS burn + mechanical prescription (i.e., Fort Gordon).

Management prescription	n	Total		Pine				Oak				Other hardwood spp.				
		% canopy cover	BA	Density	BA	Rel BA	Rel D	I.V.	BA	Rel BA	Rel D	I.V.	BA	Rel BA	Rel D	I.V.
none	30	57.9	9.46	1603.5	4.69	49.65	9.17	24.87	4.00	42.27	85.00	66.98	0.74	7.84	5.00	6.91
GS burn	30	34.8	8.27	368.2	6.98	84.39	31.67	52.79	1.29	15.61	68.33	47.21	0.00	0.00	0.00	0.00
GS burn + mechanical	60	53.4	12.42	604.0	11.79	94.89	69.87	75.33	0.63	5.10	29.71	24.19	<0.01	0.01	0.42	0.48
Young pine	20	47.9	10.71	668.8	10.47	97.76	68.75	75.71	0.24	2.24	31.25	24.29	0.00	0.00	0.00	0.00
Mature pine	40	56.2	13.23	574.9	12.42	93.88	70.44	75.29	0.81	6.10	28.93	23.99	<0.01	0.02	0.63	0.73
Non-GS burn	25	54.7	18.95	322.7	18.52	97.73	83.00	84.05	0.34	1.81	15.00	13.22	0.09	0.46	2.00	2.73

Despite having a low basal area, the 'no management' site (PSA) had the highest tree density (Figure 7 and Figure 8). The 'no management' site had the lowest pine BA and the highest oak BA values, resulting in much higher importance values for oaks than pines (Table 2, Figure 9 and Figure 10). In contrast, the non-GS burn site (i.e., SRS) had the highest total BA and pine BA but lowest tree density. The non-GS burn site consists of large trees, which were almost exclusively pine.

Like the non-GS burn site, the 'GS-burn + mechanical' site (i.e., Fort Gordon) had moderate to high total BA and pine BA. Relative to the non-GS burn site, pine in the 'GS-burn + mechanical' site had a lower importance value due to the greater abundance of oak in the understory. However, none of canopy measures were significantly different between the two sites. The younger pine stand had lower canopy cover, and slightly lower total BA, pine BA, and oak BA relative to the mature pine stands (Table 2), but these differences were not significant.

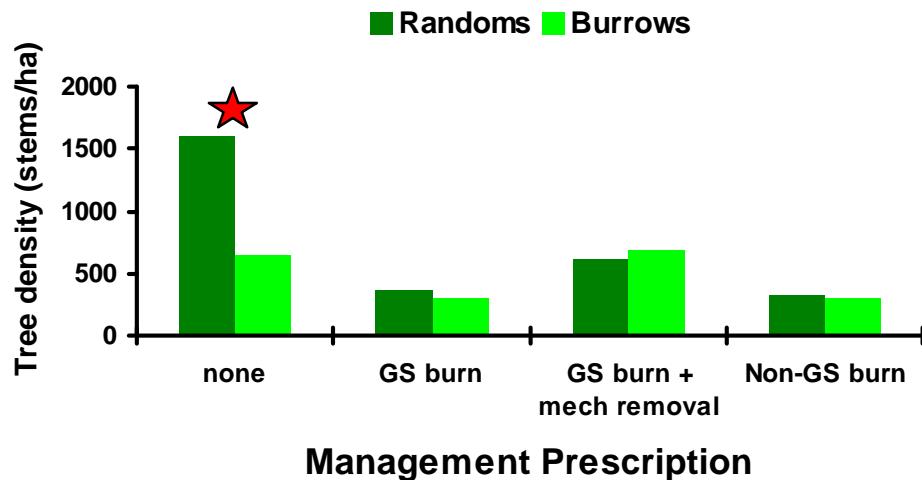


Figure 7. Tree density at random plots and burrows within each management prescription. Significant comparisons between random plots and burrow locations are noted with a star.

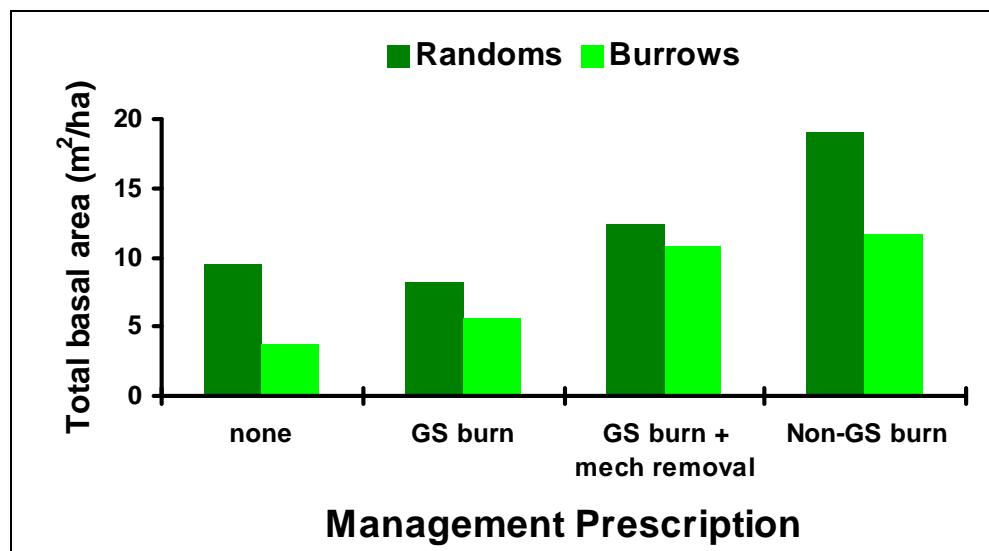


Figure 8. Total basal area (m²/ha) at random plots and burrows within each management prescription.

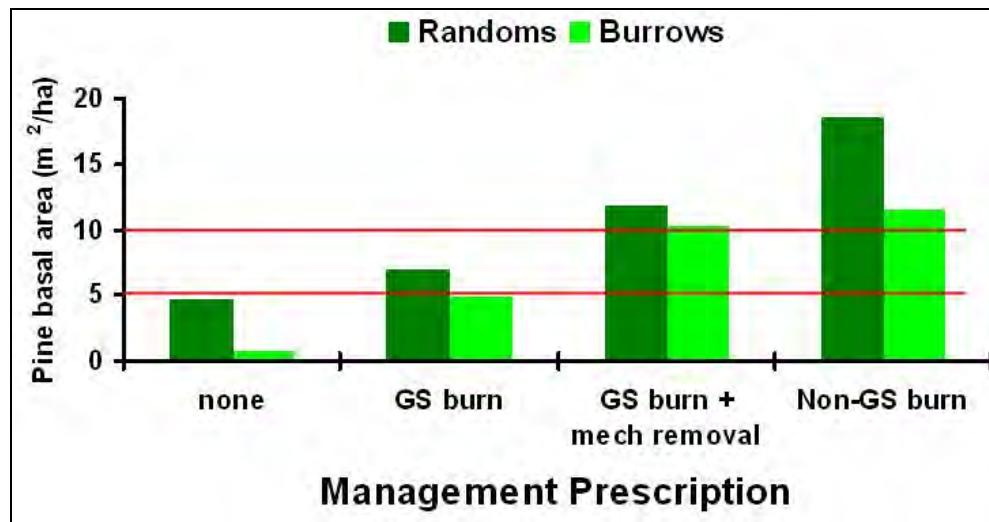


Figure 9. Pine basal area (m²/ha) at random plots and burrows within each management prescription.

The range of values recommended in the RCW recovery plan is indicated by the red lines.

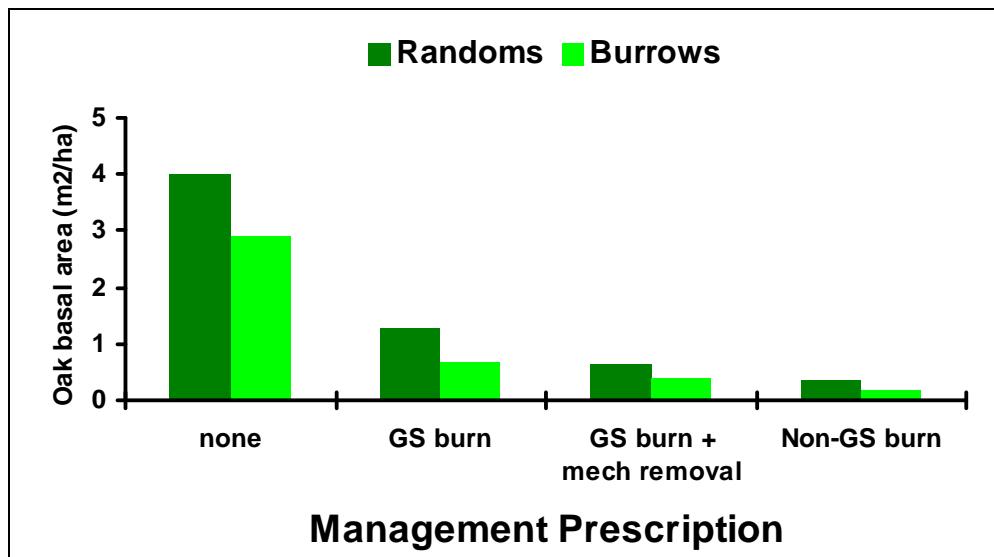


Figure 10. Oak basal area (m^2/ha) at random plots and burrows within each management prescription.

Herbaceous and Shrub Data

Available habitat at random plots was similar among the 'GS-burn,' 'GS-burn + mechanical' and the 'non-GS burn' sites with respect to the herbaceous components examined (Figure 11 through Figure 16), although the 'GS-burn + mechanical' and the 'no management' sites tended to have lower percent cover of shrubs and all herbaceous components. The GS-burn site was distinctly different in its higher shrub, wiregrass, and legume cover.

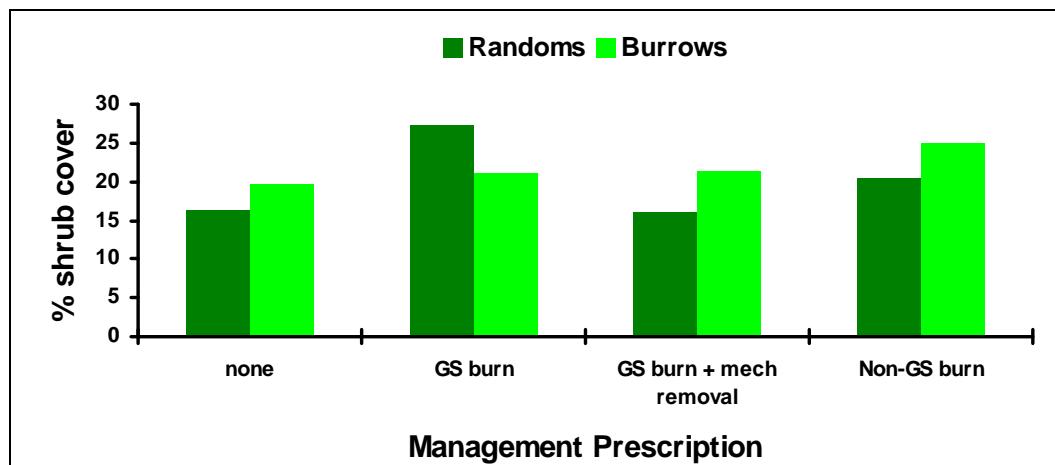


Figure 11. Percent shrub cover at random plots and burrows within each management prescription.

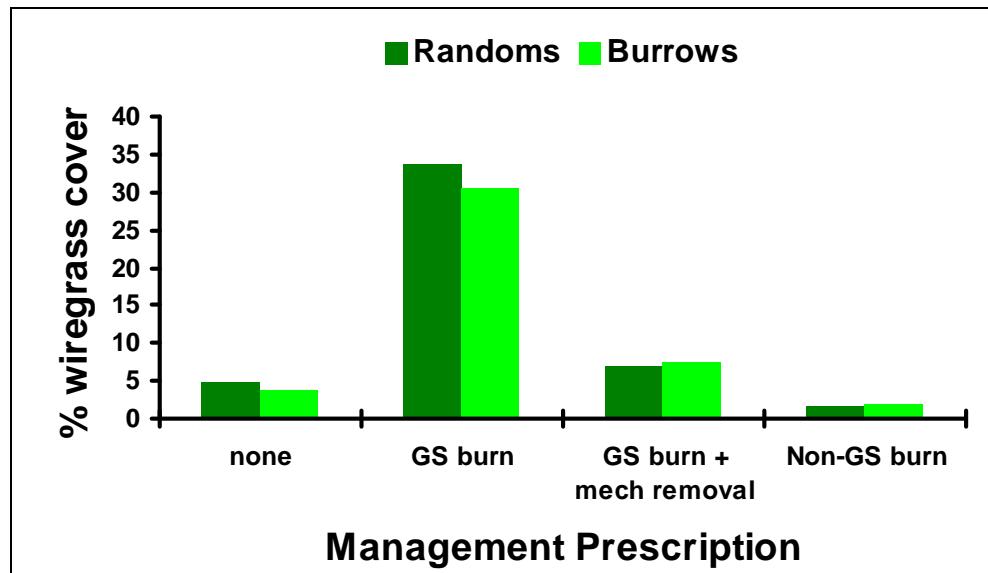


Figure 12. Percent wiregrass cover at random plots and burrows within each management prescription.

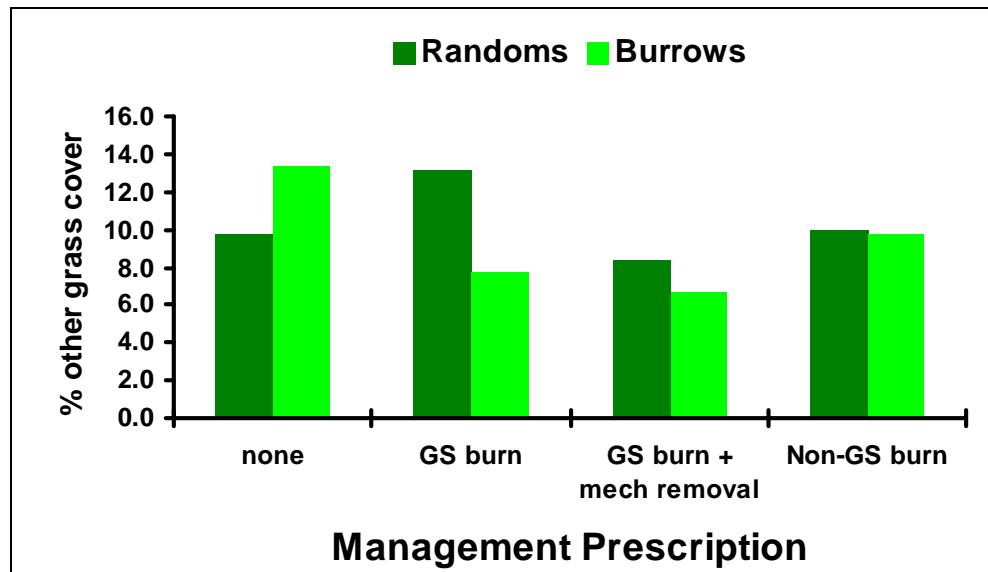


Figure 13. Percent cover of other grasses at random plots and burrows within each management prescription.

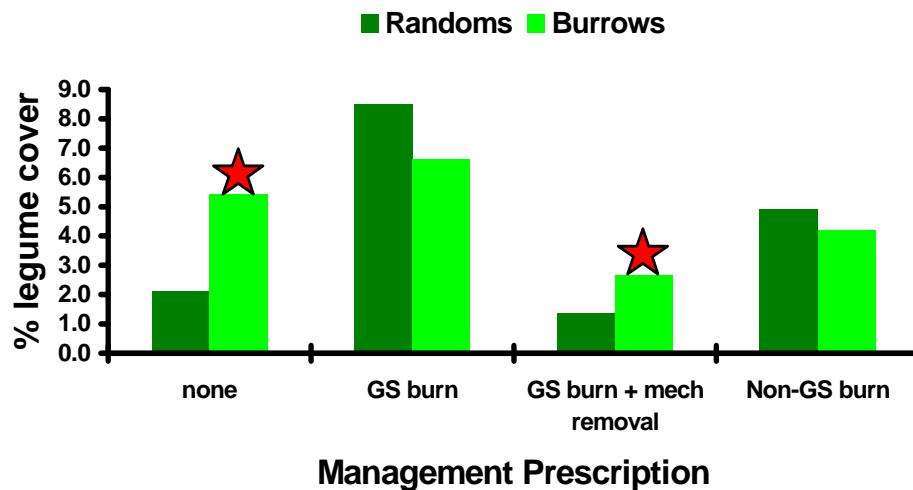


Figure 14. Percent cover of legumes at random plots and burrows within each management prescription.

Significant comparisons between random plots and burrow locations are noted with a star.

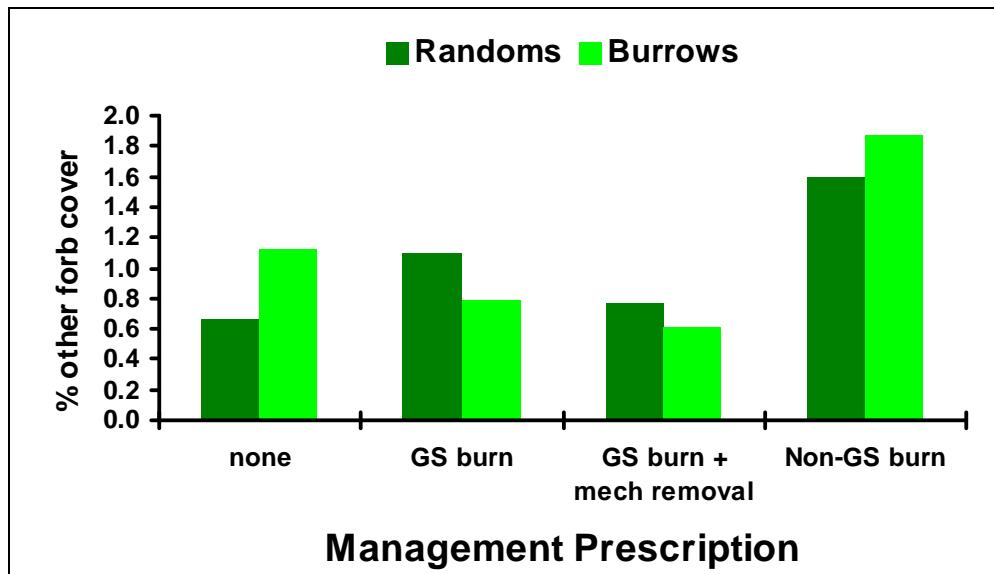


Figure 15. Percent cover of other forbs at random plots and burrows within each management prescription.

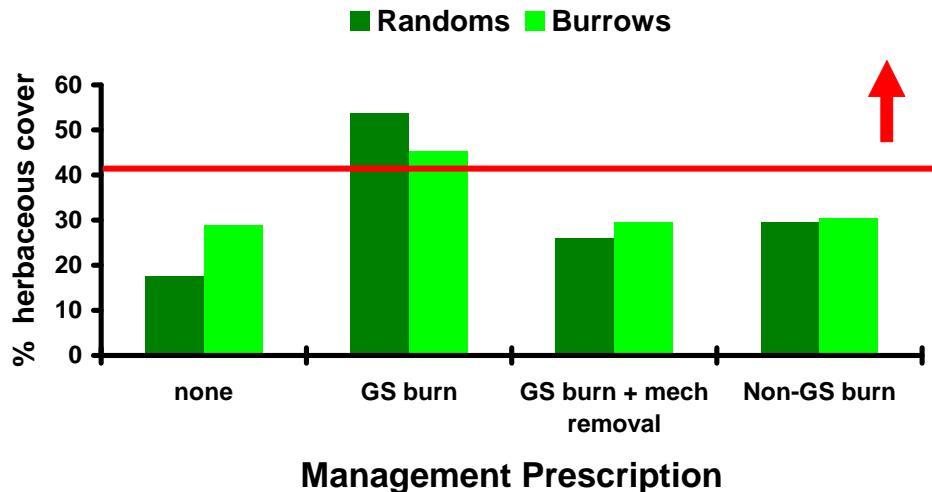


Figure 16. Percent total herbaceous cover at random plots and burrows within each management prescription.

The values recommended in the RCW recovery plan are indicated by the red line and arrow.

Comparison of Available Habitat to Tortoise-selected Habitat

Tree Data

Canopy cover was significantly lower at tortoise-selected habitat (i.e., in the square meter immediately behind the tortoise burrows) than at random plots, except when canopy cover was extremely low throughout the study site (i.e., GS-burn site) or when availability of sites with lower canopy cover was limited (i.e., 'GS-burn + mechanical'; Figure 6, Table 3). Likewise, total, pine, and oak BA were all lower at tortoise burrows than at random plots (Figure 8 through Figure 10). The only study site where habitat selection by tortoises was affected by tree density was the 'no management site', where tree density was approx. three times that of the other study sites (Figure 7).

Herbaceous and Shrub Data

With a few exceptions, herbaceous vegetation components were remarkably similar between random plots and burrows (Table 3). The most striking differences were the significantly higher percent cover of legumes at burrows relative to random plots at 'GS-burn + mechanical' and 'no management' sites—the sites with the lowest availability of legumes (Figure 14). In contrast, wiregrass (also generally presumed to be an important food item for gopher tortoises) abundance at burrows generally reflected wiregrass abundance in the available habitat at each of the study sites

(Figure 12). Percent shrub cover was higher at burrows compared to random locations except under GS-burn, which had significantly higher shrub cover in available habitat compared to other sites. Tortoises in GS-burn prescription selected sites with lower mean cover than in the available habitat, resulting in similar percent shrub cover at burrows across all management prescriptions (Figure 11). Only the GS-burn management prescription produced sufficient total herbaceous cover to meet the criteria outlined in the RCW recovery plan (USFWS 2003; Figure 16).

Table 3. Results of comparison of mean cover values for tree and herbaceous vegetation data at burrows relative to random plots under each management prescription

Wilcoxon rank sum test, alpha=0.05. Only p-values for significant (in bold) and nearly significant comparisons are reported; all other comparisons were not significant (NS).

Habitat Measure	None	GS-burn	GS-burn + mech removal	Non-GS burn
Tree and shrub data				
% canopy	0.0022	NS	NS	0.002
Basal area	NS	NS	NS	NS
Pine basal area	NS	NS	NS	NS
% pine basal area	NS	NS	NS	0.0252
Oak basal area	NS	0.0704	NS	0.0765
% oak basal area	NS	NS	NS	0.0583
Herbaceous cover data				
Shrub	NS	NS	NS	NS
Wiregrass	NS	NS	NS	NS
Other grass	NS	0.043	NS	NS
Legumes	0.0288	NS	0.0499	NS
Other forbs	NS	0.0142	NS	NS

Table 4. Summary of tree data at burrows under each management prescription.

These areas represent “tortoise-selected” habitat. Basal area (BA) is reported in m²/ha and density (D) as stems/ha. Importance values (I.V.) and relativized values of BA and D are also reported. In addition to overall means, separate means for young and mature pine stands are provided for ‘GS-burn + mechanical’ (i.e., FTG) and for tortoise-created burrows (TB) and starter burrows (SB; provided to translocated tortoises) at ‘non-GS burn’ site (i.e., SRS).

Site	n	Total			Pine				Oak				Other hardwood spp.			
		% canopy cover	BA	Density	BA	Rel BA	Rel D	I.V.	BA	Rel BA	Rel D	I.V.	BA	Rel BA	Rel D	I.V.
None	28	36.4	3.69	633.9	0.77	20.82	5.36	13.49	2.90	78.67	92.86	83.84	0.02	0.51	1.79	2.67
GS-burn	28	33.2	5.62	297.4	4.94	87.89	39.29	56.58	0.67	11.94	58.93	41.35	0.01	0.16	1.79	2.07
GS-burn + mechanical	31	47.4	10.74	691.1	10.30	96.43	75.00	78.23	0.38	3.53	24.19	20.81	<0.01	0.03	0.81	0.96
Young pine	11	47.1	13.80	954.5	13.25	97.61	77.27	79.86	0.32	2.39	22.73	20.14	0.00	0.00	0.00	0.00
Mature pine	20	47.5	9.53	590.3	9.13	95.86	73.75	77.37	0.39	4.09	25.00	21.15	<0.01	0.05	1.25	1.48
Non-GS burn	54	43.5	11.70	306.9	11.52	98.30	75.34	78.19	0.16	1.54	21.40	17.99	0.01	0.10	2.33	2.34
SB	26	48.9	15.19	326.7	14.97	98.56	81.55	81.70	0.19	1.29	16.50	15.10	0.02	0.14	0.97	1.20
TB	28	38.4	8.94	290.3	8.79	98.30	69.64	75.13	0.14	1.54	25.89	20.49	0.01	0.10	3.57	3.35

Comparison of Tortoise-selected Habitat Among Study Sites

Tree Data

Percent canopy cover and other tree measurement data were similar among tortoise burrows from the different management prescriptions (Figure 6 through Figure 10), except where stand conditions limited the range of conditions available. For example, oak BA tended to be similar ($<1\text{ m}^2/\text{ha}$; Figure 10) among burrows from different study sites, except under 'no management' where tree density was much higher at random plots compared to other study sites (Figure 7). The 'no management' site (i.e., PSA) also had lower total BA and pine BA but higher oak BA (Figure 8 through Figure 10). Although tortoises at the 'no management' site seemed to be actively selecting burrow sites that were significantly different from the surrounding habitat (based on comparison of burrows and random sites), the range of conditions selected by tortoises at other sites were not available at under the 'no management' prescription.

Within the 'GS-burn + mechanical' site at Fort Gordon, canopy cover at burrows was similar in young and mature pine stands, but total BA, pine BA, and tree density were higher at burrows in young pine stands relative to burrows in mature pine stands (Table 4). Under 'non-GS burn', canopy cover, tree density, total BA, and pine BA were significantly lower at tortoise-created burrows (TB) compared to starter burrows (SB) provided to tortoises at the beginning of the translocation project (Table 4), even though only starter burrows used by tortoises were included in the analysis.

Herbaceous and Shrub Data

Percent shrub cover at burrows was 20 to 25 percent at all study sites (Figure 11). Burrows in 'GS-burn' had significantly more wiregrass than at any other site (Figure 12), while burrows in 'Non-GS burn' had significantly more cover of other forbs than did other sites (Figure 15). However, the observed differences at burrows reflected differences in abundance in the available habitat. The only difference in herbaceous vegetation among burrows that does not appear to reflect abundance in available habitat is the high percent cover of other grasses at burrows under the 'no management' prescription (Figure 13).

At the 'GS-burn + mechanical' site, percent cover of shrubs, wiregrass, and other grasses was higher at burrows in young pine stands than at burrows from mature pine stands. At the translocation site under 'non-GS burn', tortoise-created burrows had higher percent cover of shrubs and other grasses than did starter burrows. Although starter burrows had higher percent wiregrass cover than did tortoise-selected burrows, this is most likely due to the footprint of the wiregrass restoration project being confined to the area where starter burrows were constructed (Tuberville et al. in press).

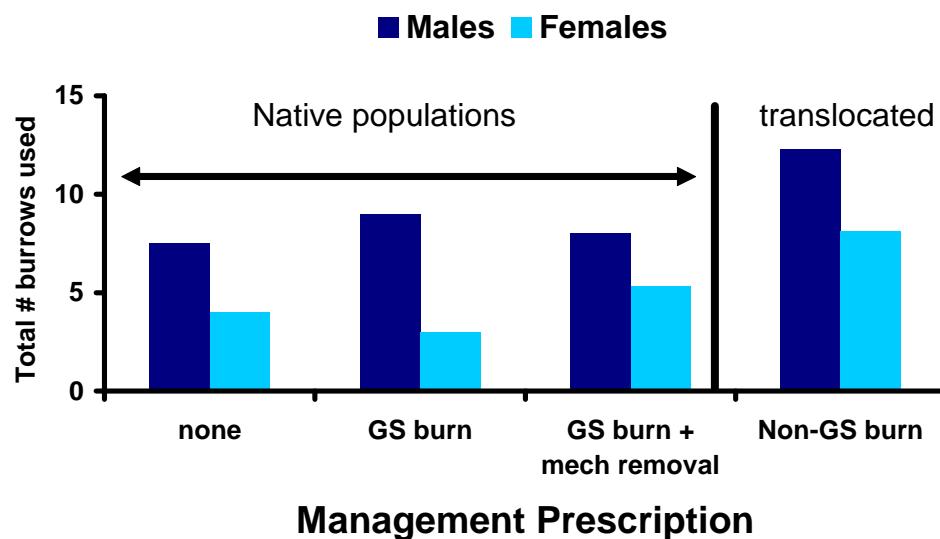


Figure 17. Number of burrows used during the 2 yr study period (2003-2004) by males and females under different forest management prescriptions.

Summary of Major Findings

- RCWs and gopher tortoises have similar (but not identical) habitat requirements that suggest that the two species can be managed simultaneously.
- Habitat varied significantly among the four management prescriptions. Differences were due primarily to canopy structure and composition (total, pine, and oak basal area). The 'no management' prescription (PSA site) was the most different from all other management prescriptions.
- The primary differences in herbaceous vegetation were the extremely high wire-grass cover at the 'GS-burn' site (TSR) and the low percent-

age of legume cover at the ‘no management’ (PSA) and ‘burn + mechanical’ site (Fort Gordon).

- Tortoises selected burrow sites with 20 to 25 percent canopy, which was lower than the mean percent canopy available under all management prescriptions except ‘GS-burn.’ Under ‘no management site,’ tree density in the available habitat was extremely high and tortoises selected burrow sites with significantly lower tree density than in surrounding available habitat.
- Where the availability of legumes was limited (under ‘no management site’ and ‘burn + mechanical’), tortoises used burrows that had significantly higher percent legume cover.
- Despite the differences in available habitat observed under the different management prescriptions, the burrows at those sites were remarkably similar to each other with respect to the vegetation parameters measured.
- Anecdotal observations made during the course of this project indicate that population demography may vary among the different management prescriptions, with juveniles and hatchlings being notably absent or scarce at the ‘no management’ (PSA) and ‘GS-burn + mechanical’ (Fort Gordon) sites. The potential effects of habitat management for RCWs on female reproductive success and juvenile recruitment in gopher tortoises should be examined.

5 Conclusions and Recommendations

Comparing These Results to Previous Studies

Regardless of management prescription, tortoises generally selected burrow locations with 30 to 50 percent canopy cover, approximately 20 percent shrub cover, and lower basal area (total, pine, and oak) than in surrounding available habitat. Although it can be an important food item when other forage is not available (such as in the early growing season; Garner and Landers 1981), wiregrass abundance at burrows varied with management prescription but generally reflected its availability in the surrounding habitat. Under management prescriptions in which forage availability was limited, legumes—also considered to be an important food item (Garner and Landers 1981)—were significantly more abundant at burrow sites than in surrounding available habitat.

Habitat selection and space use by tortoises in this study may have been limited by the range of some habitat variables available for them to choose from (e.g., total herbaceous cover, tree density, etc). In addition, this study did not control for—nor do we fully understand—the potential legacy effects of previous land use and land management history. However, the fact that tortoises consistently selected sites with certain structural features (especially canopy measures) across a wide range in available habitats, suggests that specific management targets for tortoises can be developed. The reported values for canopy cover, as given above, are not surprising to anyone who has studied tortoise distribution even casually, but represent the first comprehensive reports of actual cover values across a wide variety of habitats and management practices. In addition, because these burrow site selection patterns were exhibited even by translocated tortoises, habitat manipulation—in combination with other release techniques—may prove to be a useful tool in promoting successful establishment of translocated gopher tortoises at their release site. Habitat assessment can also be used to screen potential release sites. It would appear that the site selected for release of the translocated animals did prove generally satisfactory in practice, as well as comparing well statistically with the measures for “tortoise selected” habitat which were derived 3 years after the original relocation project.

Determining Management Compatibility between Gopher Tortoise and RCW

Obviously, RCWs and gopher tortoises do not always occur sympatrically. For example, RCWs can inhabit sites that are too mesic for gopher tortoises as long as the appropriate habitat structure is there (USFWS 2003). Likewise, gopher tortoises can thrive in areas that are not considered either nesting or foraging habitat for RCWs (e.g., treeless habitats, scrub lacking pine trees, and pine forests \leq 30 yrs old). However, there is broad overlap between types of macro- and micro-habitats that support both species and in the management prescriptions that are used to manage those habitats. Further, the matrix of available habitat may be complex, with many patches suitable for tortoises and not woodpeckers, or vice versa.

Recommendations

The general habitat guidelines provided in the recovery plans and recommended in the scientific literature are quite similar for both species—longer timber rotation, lower stem density, frequent growing-season fire, replacement of offsite pines with native pines, etc. (Berish 2001, USFWS 2003, Wilson et al. 1997). For both species, growing-season fire is preferred over non-growing-season burns and use of mechanical or chemical hardwood control, which are recommended only for sites in need of intensive management or where growing-season fire is difficult or impossible to implement. However, gopher tortoises, because of their fossorial behavior and herbivorous diet, may be more susceptible than RCWs to the use of mechanical or chemical treatments (Cox et al. 1987, Wilson et al. 1997). Use of phenoxy or other broadleaf herbicides on herbaceous groundcover may be particularly damaging to the tortoise forage supply.

The specific management targets recommended for RCWs, especially those in the 2003 recovery plans, seem compatible with management of gopher tortoise populations. Further studies investigating the importance of legacy effects will help refine management targets so that these species can be managed simultaneously, particularly at sites in need of intensive management.

These studies were carried out at four sites close to the extreme northeastern limit of distribution of the gopher tortoise. It is not possible to be certain that the same measurements of preferable canopy cover will be uni-

versal throughout the range of the tortoise, although it is reasonable to believe that the same general principles are applicable. Army installation forest and wildlife management planners should follow, where appropriate, understory and canopy management guidelines for the RCW until more specific modifications of these prescriptions are developed to specifically accommodate the gopher tortoises living in the same areas. For installations that do not manage for the RCW, but do have gopher tortoises, following the RCW management guidelines will provide good interim management criteria for responsible tortoise management.

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